DETECTING LARGE SCALE TRAVELING IONOSPHERIC DISTURBANCES USING FEATURE RECOGNITION AND AMATEUR RADIO DATA

APPLYING DATA SCIENCE TO IONOSPHERIC PHYSICS

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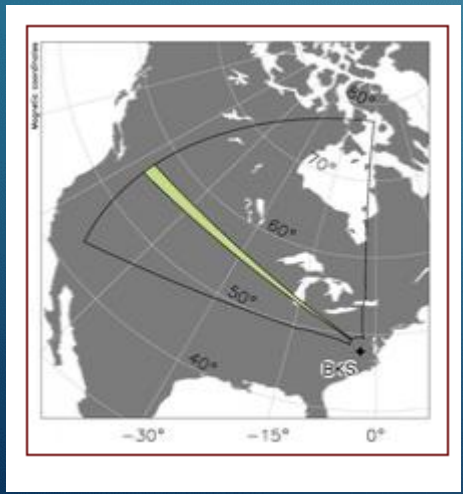
INTRODUCTION

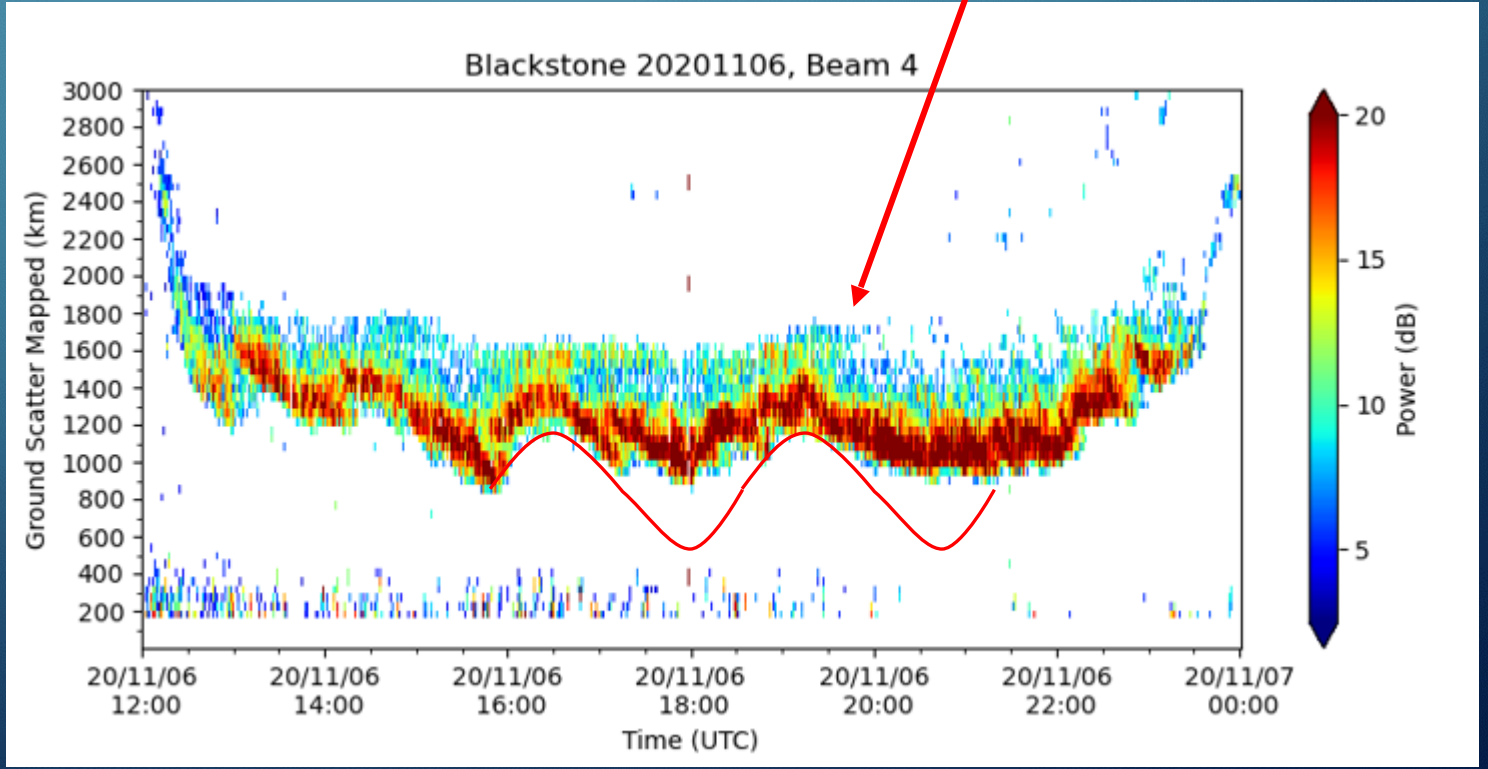
- Transient Ionospheric Disturbances are electron density waves that travel through the ionosphere and affect HF propagation (QSB, fading, etc.)
- We can see these waves in spot data from PSK, RBN, WSPR
- New technique developed to recognize these using Machine Learning

OBSERVING TIDS IN HF RADAR

- Traditional way of observing TIDs
- Virginia Tech SuperDARN HF Radar



LSTIDs:
Period of 1 to 4 hours



WHY USE SPOT DATA?

- We have spot data for many days where HF Radar was down or in maintenance
- There is spot data for some areas not covered by HF Radar
- TID analysis can reveal improved understanding of HF propagation (how underlying solar & geomagnetic environment drives it)

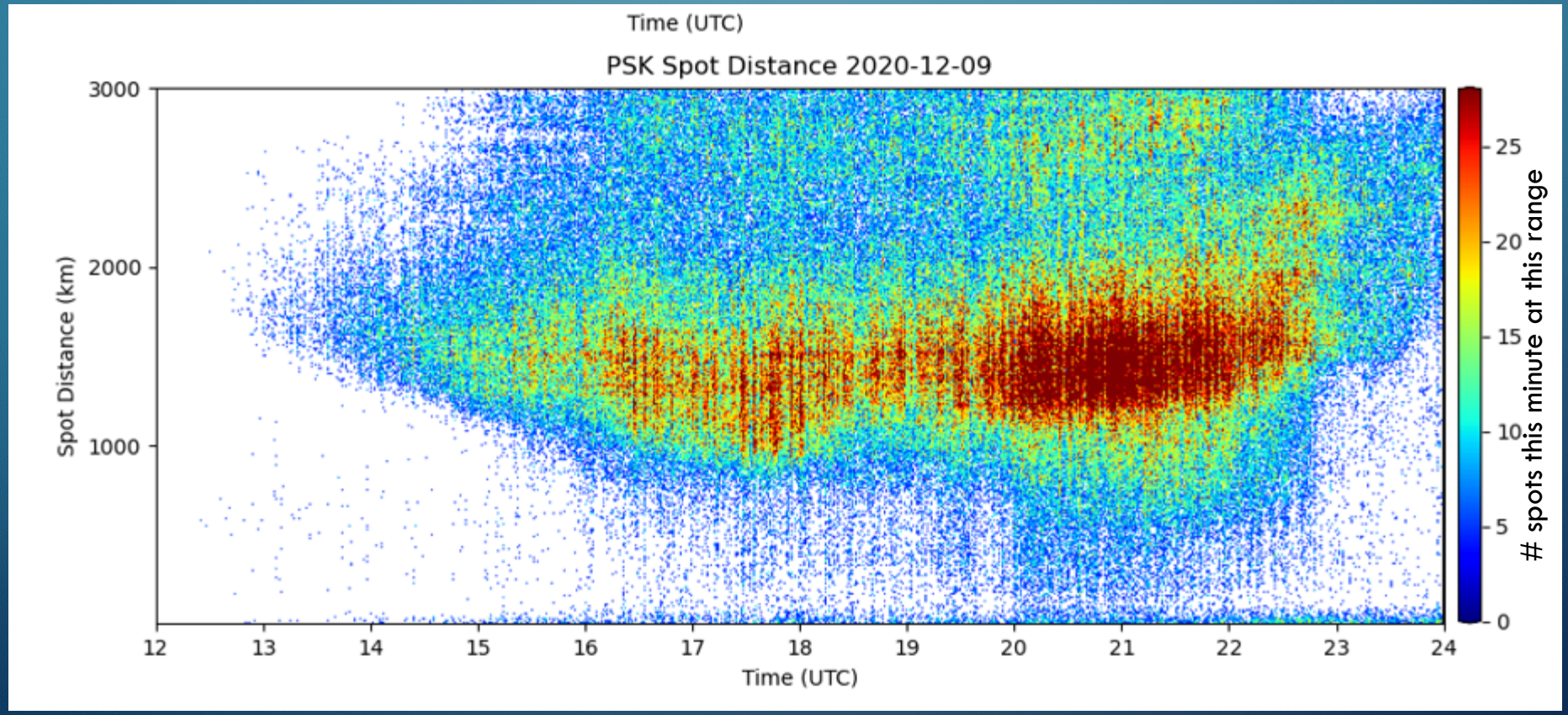
SPOT DATA SOURCES

- WSPR: wsprnet.org
- RBN: http://www.reversebeacon.net/
- PSKReporter: https://www.pskreporter.info/

REPRESENTING SPOT DATA

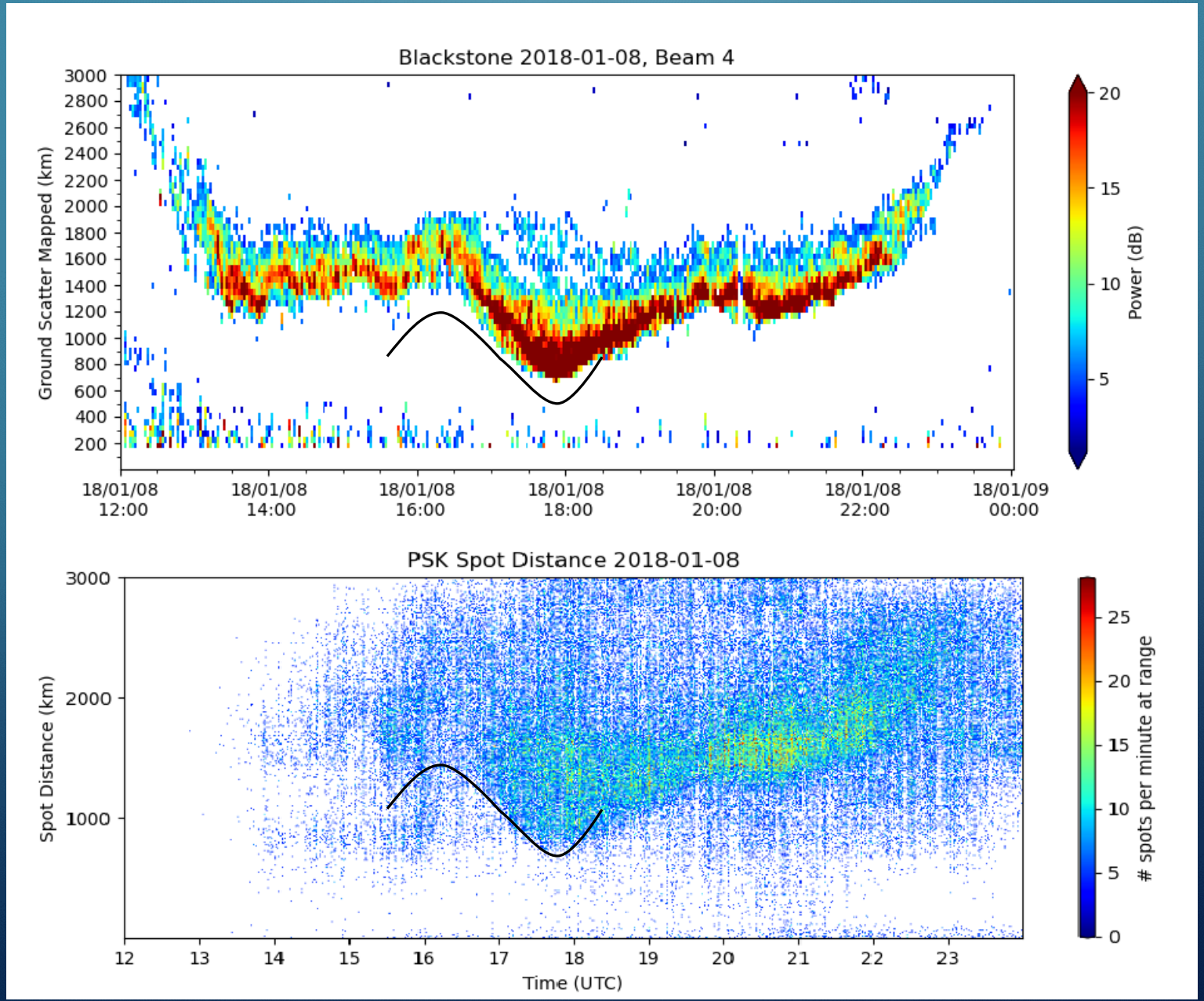
- Show data for direct comparison to SuperDARN plot
- X axis: UTC 1200 to 2400
- Y axis: spot signal distance in km
- Point color: number of spots this minute at this range

PSK spots example plot – 20 meters (mostly FT8)

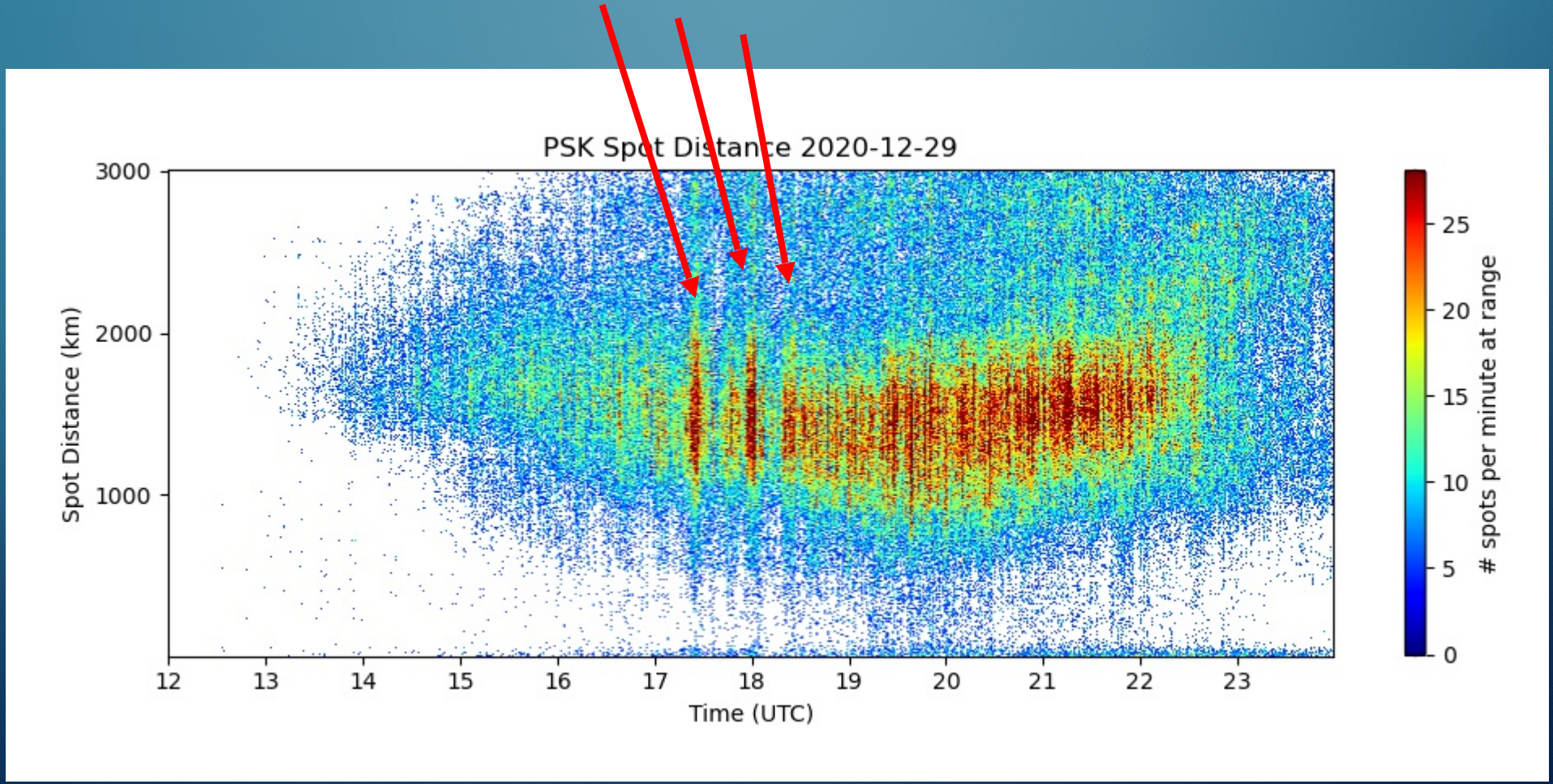


We can also include WSPR and RBN spots in a single chart (looks similar)

TIDs can be observed in both the HF Radar and spot data plots



P.E.P. - Periodic Enhanced Propagation – need to analyze this
Is it a processing artifact or actual propagation?



USING MACHINE LEARNING TO DETECT TIDS

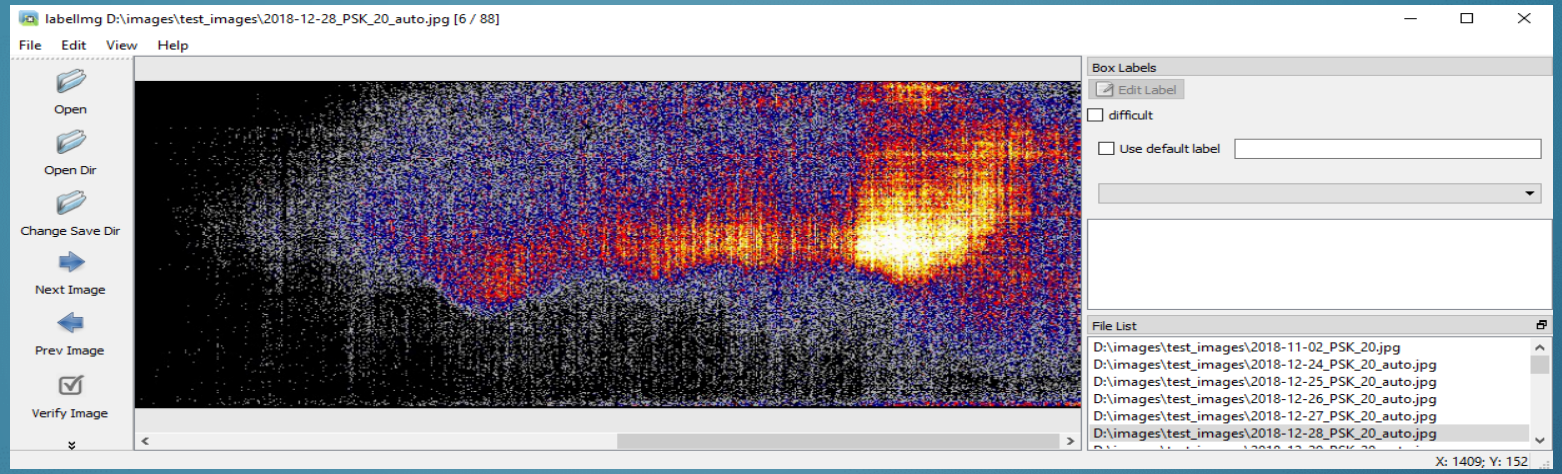
- Using Tensorflow
- Open source
- Object detection model
- Concept: manually identify the shapes in the plot that correspond to TIDs seen in HF radar; train based on these

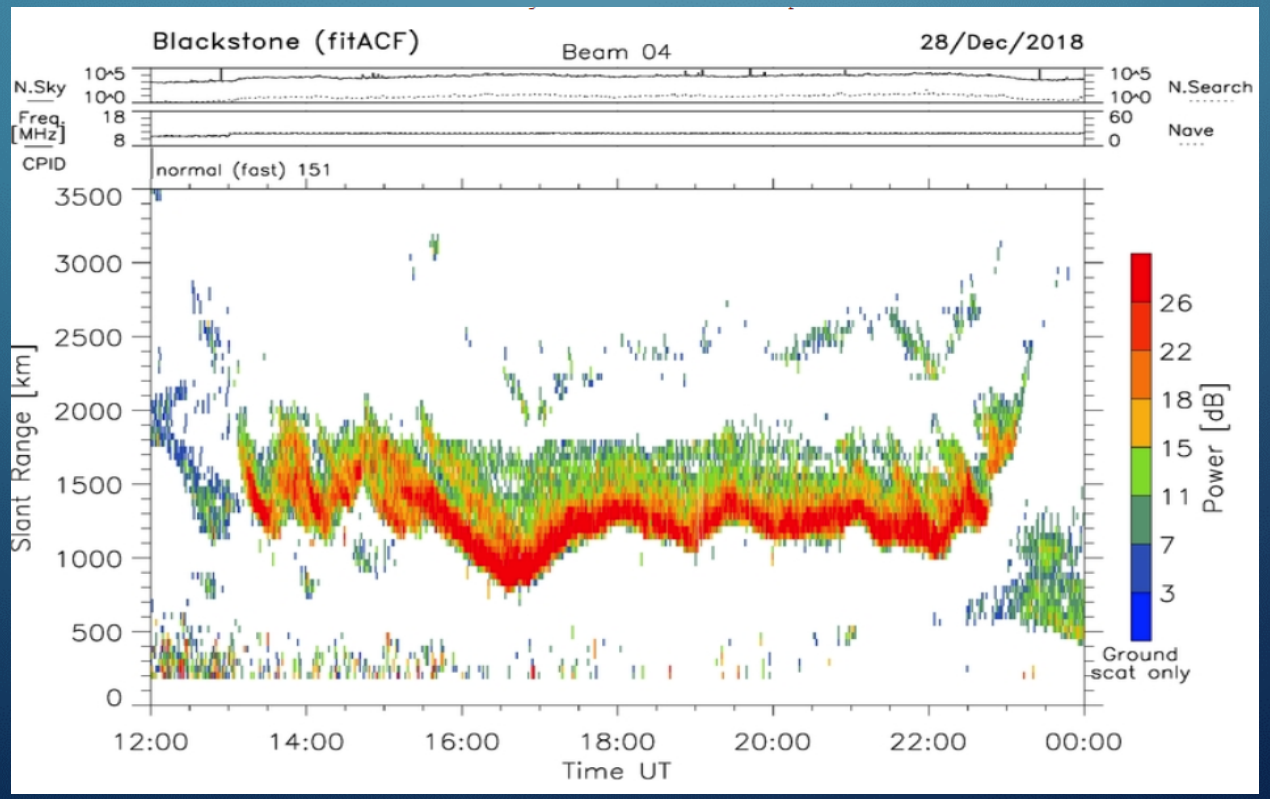
TRAINING AND TEST SETS

- Should have several thousand images
- Randomly split images into 80% training and 20% test
- Go thorough images manually and mark features

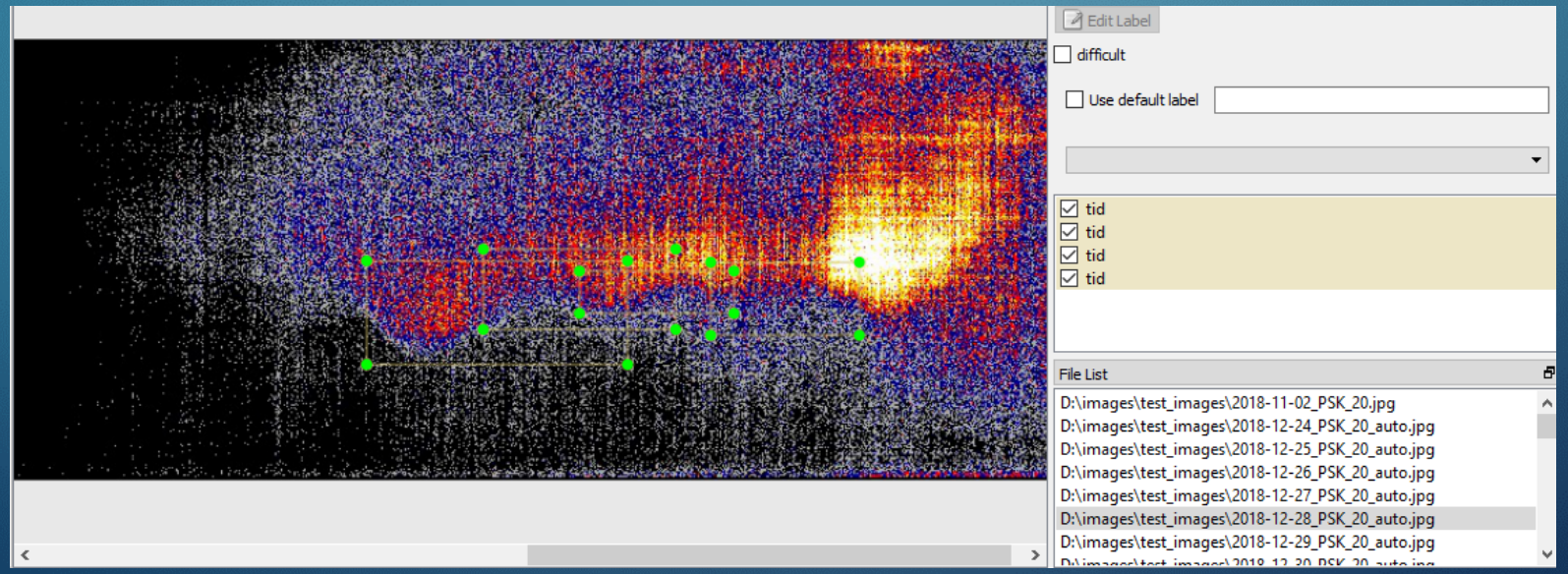
TRAINING

1. Make spot plot
2. Plot HF radar data for corresponding time frame; verify presence of TIDs in both images





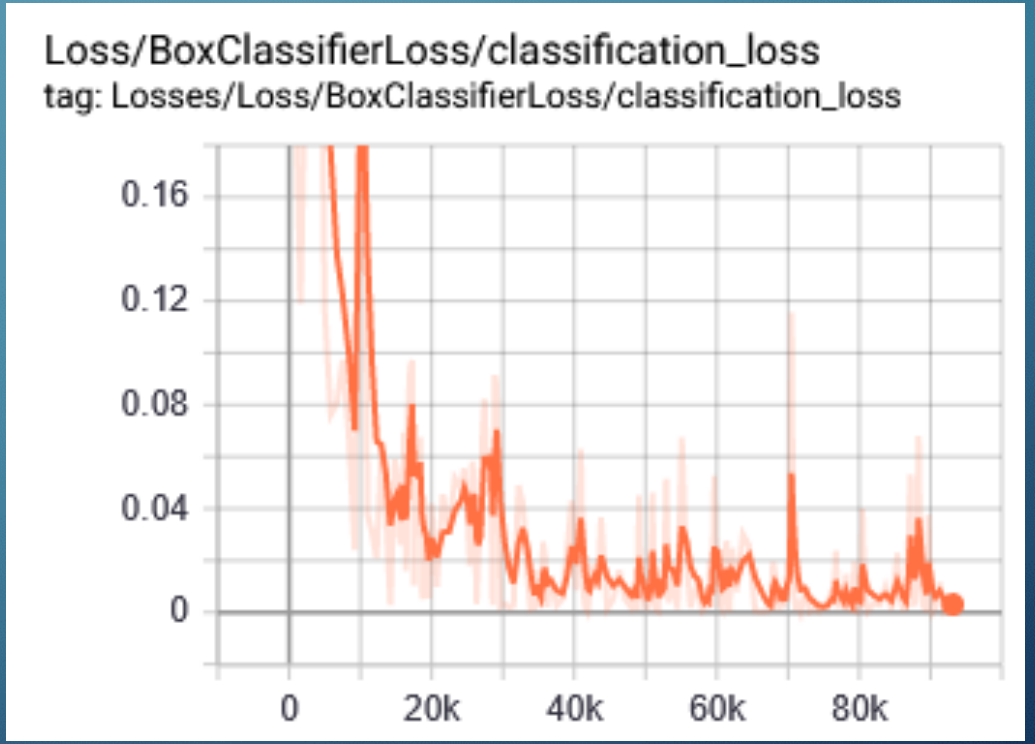
1. USE LABELIMG PROGRAM TO IDENTIFY DESIRED FEATURES



Used PSK plots for years 2016 through 2019 (4 year's worth)

2. RUN TRAINING PROGRAM

- "Loss" indicates difference between system's assessment and human assessment
- As loss decreases in training steps, the system "learns" to recognize the desired features through generalization
- Using GPU cuts training time by over 80% (still takes 6 to 8 hours)

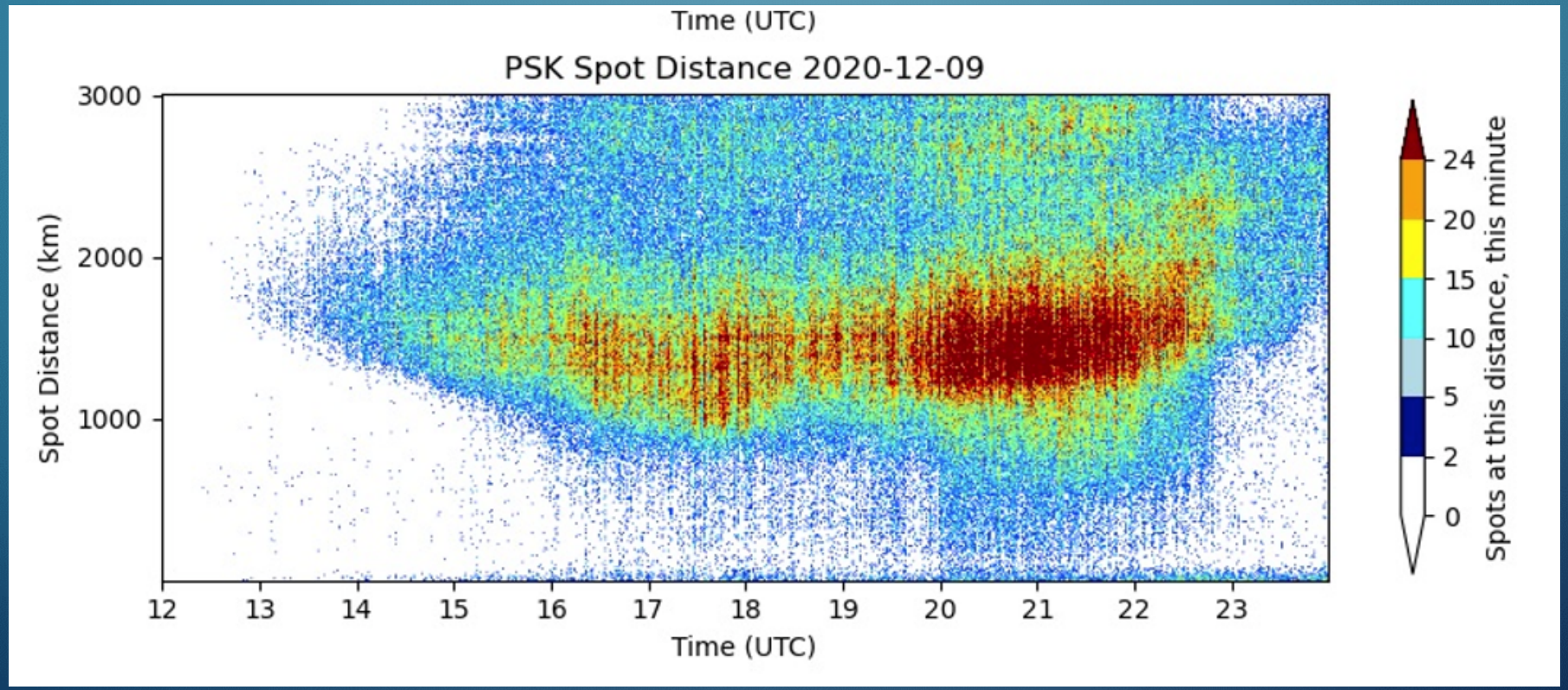


Output of the training run is an Object Detection Model

USING THE OBJECT DETECTION MODEL

- Using the Model, the Detector program searches an image for a sub-image that looks like the object(s) it was trained for
- Compensates for scale
- Can sometimes find a feature in the image that is obscured and not immediately recognizable by human eye

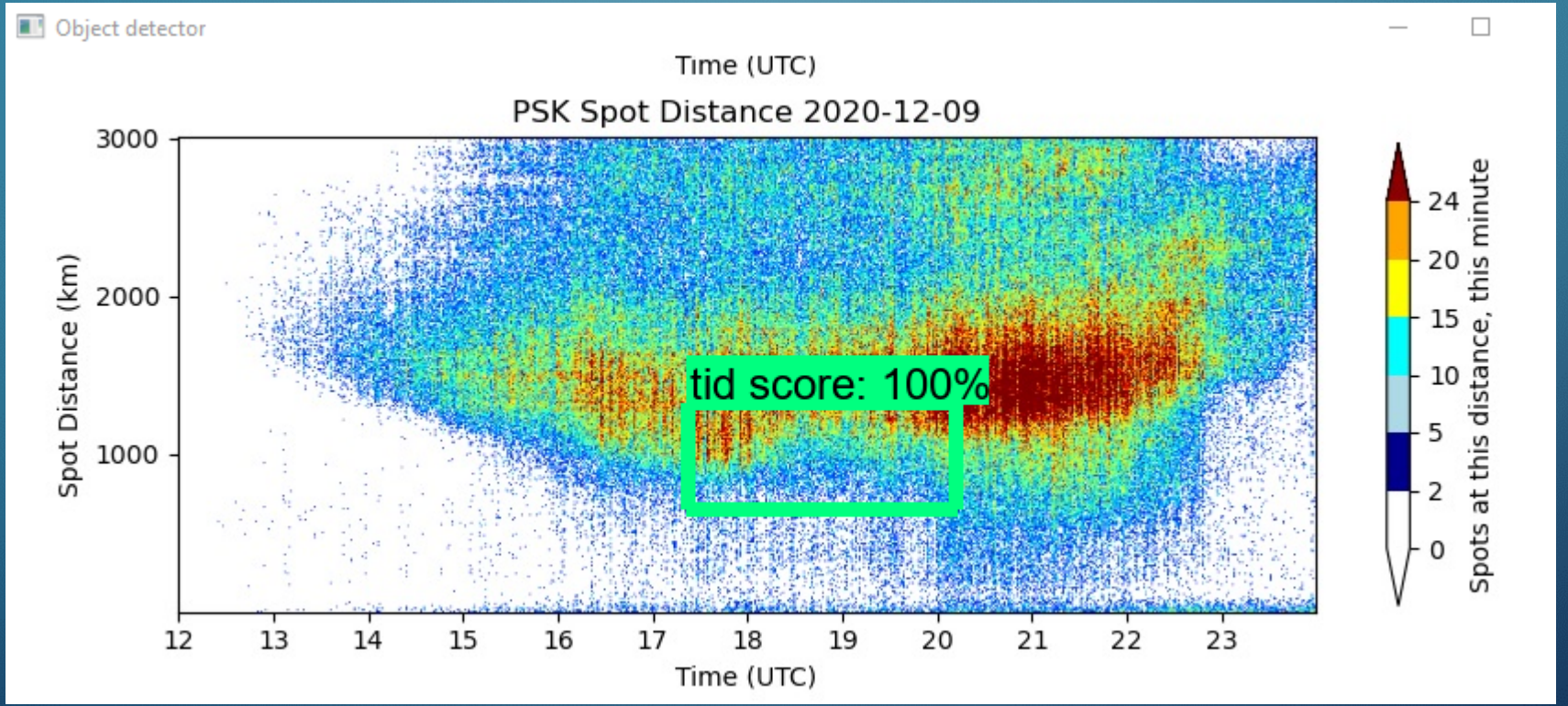
TESTING THE OBJECT DETECTOR



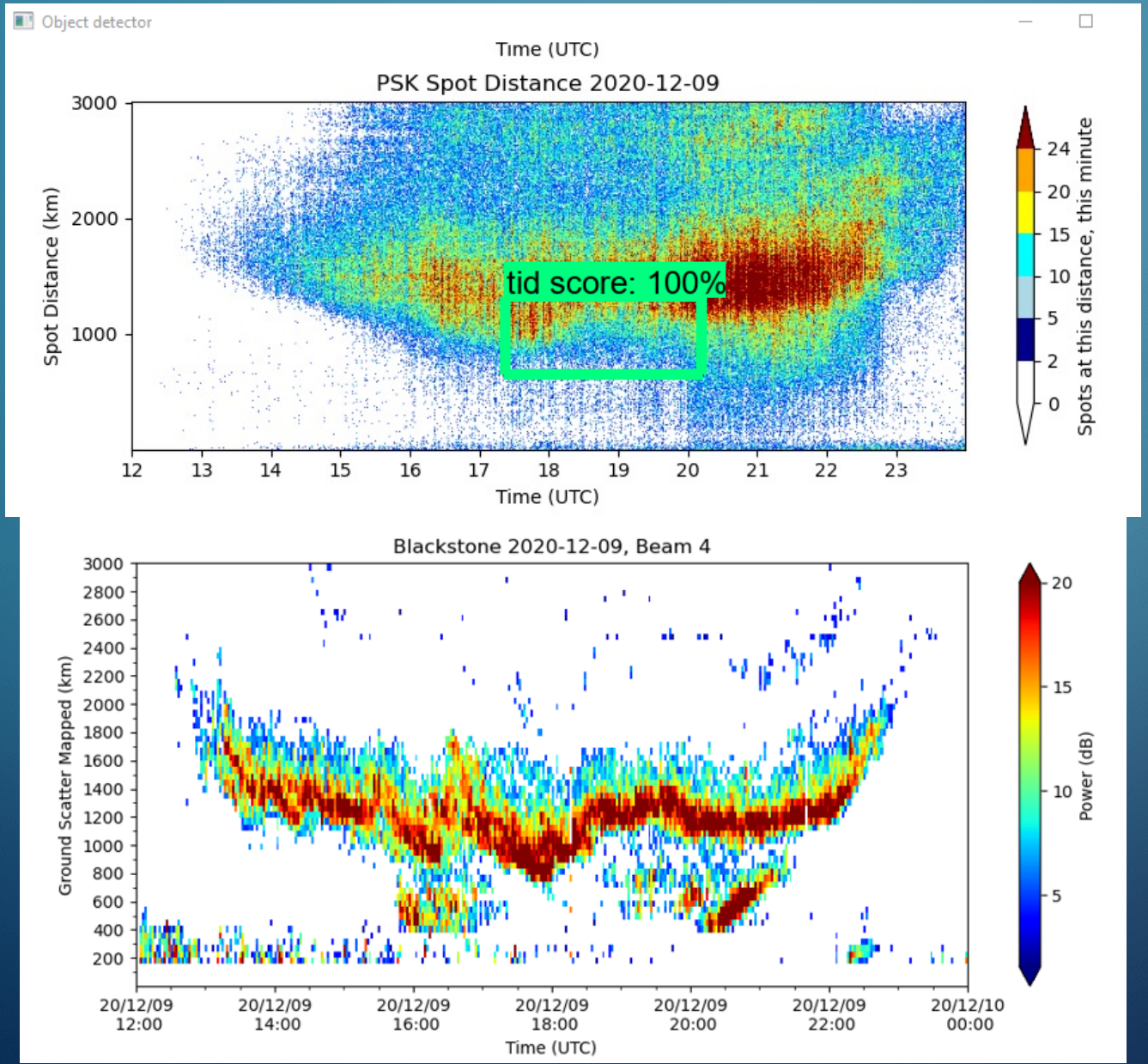
Select a spot plot from a year not included in the training set;
Run the object detection program

Output of Object Detection program is an image annotated with any TIDs detected, each with a confidence score.

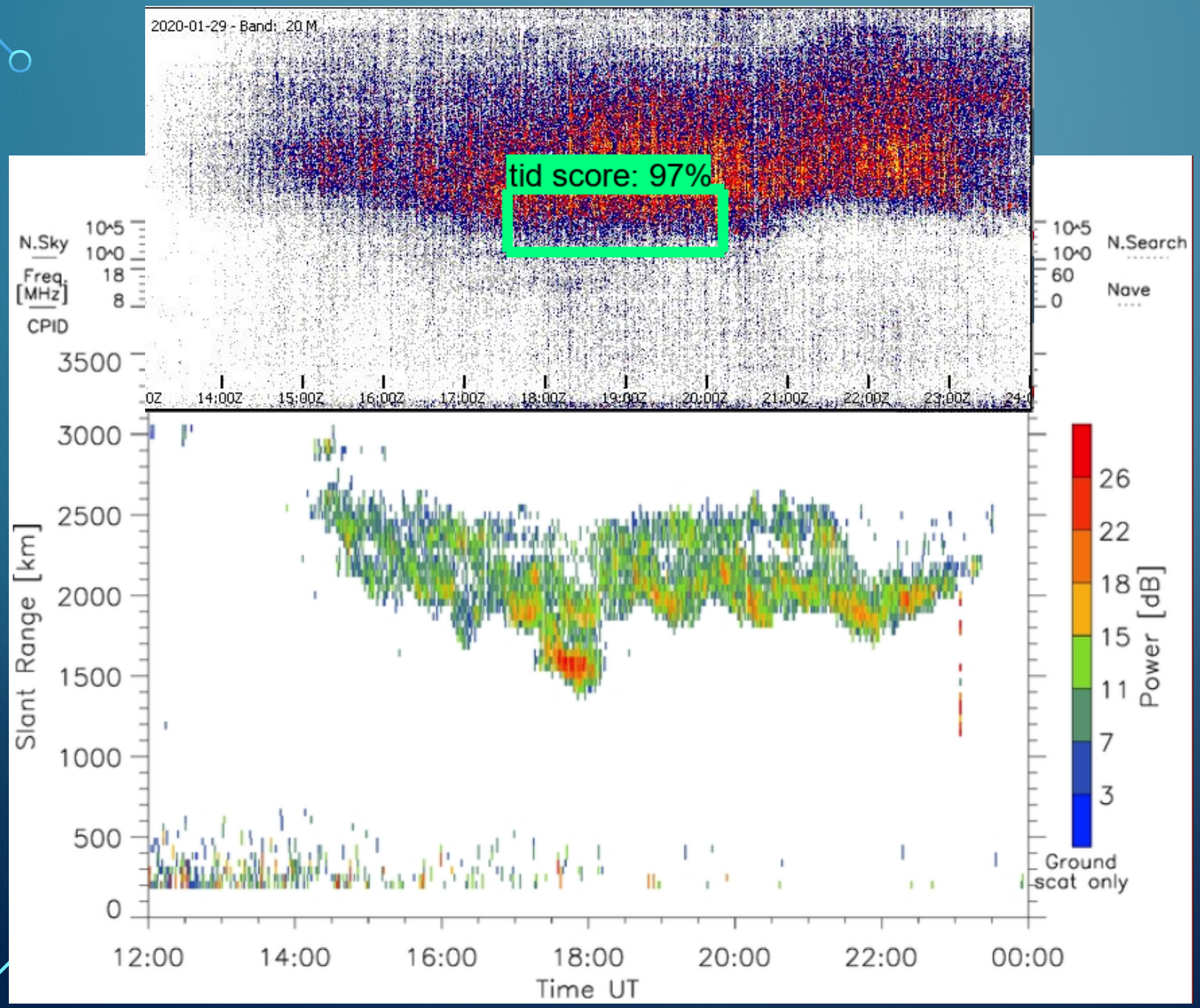
Object detector spots a TID in the image



The high level of confidence indicates that this TID is very similar to one that was identified in the training set.



SuperDARN plot confirms the presence of one or more TIDs on this date



In some cases, the Object Detector finds a TID that is not clear to the human eye. We see evidence in the SuperDARN plot for this date.

NEXT STEPS

- Re-do the training with more years of data, and also including PSK, WSPR, and RBN (proof of concept training used PSK data only)
- Apply the object detection system to historical data for climatology studies

PLANNED USE: CLIMATOLOGY STUDIES

- System can examine several images per second (up to 30 frame per second video, when GPU-accelerated)
- Allows us to study years of propagation reports for correlation analysis with solar and geomagnetic factors
- May lead to improved understanding of TIDs, influence of various factors on HF propagation & GPS accuracy

ACKNOWLEDGEMENTS

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  - Thanks to Virginia Tech SuperDARN team for use of the North America data

Q & A

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